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Neotrombidiidae (Acari, Trombidiformes) from Nullarbor caves, southern Australia including the apparently troglomorphic *Cruralonga* gen. nov.

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Abstract

Nullarbor caves were sampled during the Yalata Bush Blitz 2021. Collecting methods commonly used above ground were employed. A large diversity of cave mites and other arthropods were uncovered, including two genera of Neotrombidiidae showing remarkable extremes in larval body form. The first of these genera, *Cruralonga* **gen. nov**. (Gracile Velvet mites) has unique features, such as elongate appendages and unusually large numbers of leg sensory setae. Morphotype adults matching these larvae were found widespread in the Nullarbor karst and these also possess putative troglomorphic traits, with longer appendages than previously recorded for the family, and loss of the posterior pair of eyes. Two other species from eastern Australian caves, formerly *Neotrombidium*, are also transferred to this genus. The second cave-dwelling taxon, has a compact larval body form and a separate set of unique characters such as an expanded anterior region of the scutum and setae on coxa II modified as spurs. It was collected from the folded wings of a trogophilic beetle. Integrative systematics of Australian cave-dwelling Neotrombidiidae could offer a previously unexplored insight into troglomorphic adaptation.

Keywords

Gracile Velvet mites, heteromorphic, metamorphosis, *Monunguis*, parasite, Parasitengona, Tenebrionidae

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Introduction

The diverse mite cohort Parasitengona (ca. 7000 spp.) includes familiar velvet mites, water mites and chiggers, and have a life cycle where parasitic larvae undergo metamorphosis, moulting to free-living stages as nymphs and adults. Depending on habitat usage, different parasitengones tend to be collected either as larvae, or as heteromorphic postlarvae, and this has created a legacy of a dual taxonomy. This is most acute in superfamily Trombidioidea sensu lato (Costa et al. 2024) but also in some other non-erythraeids where larvae are seldom collected (Costa et al. 2021). Descriptions based on postlarvae typically require correlation with larvae by rearing or molecular study (Mąkol and Gabrys 2005). This dual taxonomy affects even the small, phylogenetically-enigmatic family Neotrombidiidae. Collections of parasitic neotrombidiid larvae have resulted in descriptions of 14 species in two genera, whereas descriptions of the larger free-living postlarval stages have resulted in 12 species in three genera. The overlap between these lists, where postlarvae and larvae are confirmed to be the same species, is only two species within the widespread nominative genus *Neotrombidium*.

Fundamentals of Neotrombidiidae systematics have been reviewed by Southcott (1957), Singer (1971a), and Lindquist and Vercammen-Grandjean (1971). These works focused on the cosmopolitan *Neotrombidium* and the neotropical *Monunguis*. Two other genera, poorly known and based solely on postlarvae, are also currently inferred to belong to this family. The monobasic neotropical *Discotrombidium villasiense* Feider, 1977, known only from distinctive postlarvae from bat guano in a Cuban cave, has been considered related to *Neotrombidium* in sharing triradiate body setae. The litter-dwelling African genus, *Anomalothrombium*, awaits detailed study. It includes the distinctive *A. curiosetosum* Meyer & Ryke, 1960, and at least four other species (Vercammen-Grandjean 1973).

The morphological similarity of chiggers in the Leeuwenhoekiinae with the chigger-like larval Neotrombidiidae have provoked long-standing systematic and phylogenetic questions about these larvae, which parasitise vertebrates, and invertebrates respectively. Amongst the latter, *Monunguis streblida* Wharton holds a special status. It has a truly obligate ecological association with an invertebrate host (the parasitic streblid flies on which it parasitically feeds), while it also lives in intimate proximity to various neotropical bats, on which these flies feed. *M. streblida* is the only consistently hyperparasitic taxon within the Parasitengona. Its cave association raises interesting questions about the transition to vertebrate parasitism within this superfamily.

The vertebrate-parasitic Parasitengona (i.e. chiggers), match a classic delimitation of the Trombiculoidea and are currently considered a natural group as the epifamily Trombiculoidae. These have medical significance and up to 3100 species (Zhang et al. 2011). Understanding the origin of this group has required ongoing research of a diverse array of small families of Trombidioidea including taxa sometimes hypothesized to represent key evolutionary transitions within terrestrial Parasitengona. Southcott (1987) discussed characters, revising the systematics of four families regarded as closely

related to Trombellidae, and supplementing one of the few descriptions of Trombidioidea from rhaphidophorid crickets. This group of four families matches the current concept of the epifamily Trombelloidae, except omitting Neotrombidiidae. A cladistic analysis by Welbourne (1991) reconstructed a different arrangement, accepted by Zhang et al. (2011), providing an expanded delimitation of the Trombiculoidea that included Neotrombidiidae. However this grouping was not subsequently recovered in a wide-ranging molecular phylogeny (Costa et al. 2024). In this phylogeny Neotrombidiidae was found to be nested within a clade of four invertebrate-parasitic Parasitengona, as: (((Neotrombidiidae, Trombellidae), Chyreziidae), Johnstonianidae). This clade was recognized as the epifamily Trombelloidae, and also includes the scorpion-parasitizing Audyanidae – added on morphological evidence. This new epifamily was recovered as sister to other Trombidioidea (five other families of invertebrate-parasitic taxa, plus the vertebrate-parasitic Trombiculoidea). The relationships above were recovered with strong support across four different partition schemes, offering a robust phylogenetic framework for further investigation. Given the infrequent collection from key families, further advances with even more comprehensive sampling can be anticipated.

Within Neotrombidiidae, a close relationship of *Neotrombidium* and *Monunguis* has long been accepted (Lindquist and Vercammen-Grandjean 1971). Southcott (1954) even synonomised *Monunguis* and *Neotrombidium*, citing shared characteristics. In a detailed study, Lindquist and Vercammen-Grandjean (1971) redescribed *Monunguis*, identifying intrinsic, genus-distinctive characters, most notably in the leg sensory setae, and re-established *Monunguis* as a separate genus.

However, questions remain regarding the placement of other described species within *Neotrombidium*. Relevant for this study, Lindquist and Vercammen-Grandjean (1971) did not mention the two nominal species of cave-dwelling *Neotrombidium* described from south-east Australian caves (Womersley 1963a, b). This omission suggests that their genus placement was considered uncertain. Indeed, Singer (1971a) did question the classification of *Neotrombidium gracilipes* Womersley, recognizing it as distinct, and probably requiring a new genus.

Neotrombidiidae have a notable affinity for caves and understanding this uncommonly reported family hinges on future sampling from a variety of karst areas worldwide. Known cave-dwelling taxa include *Neotrombidium helladicum* Cooreman, 1960, from Greece (currently synonomised with *N. indosinesis* on inadequate criteria), species from Central America, including Yucatan and the Caribbean (*Monunguis*, *Discotrombidium*), as well as undescribed material from North America, where postlarval instars of putative *Monunguis* have been found in a Missouri cave (Krantz and Walter 2009). Additional undescribed material from Brazil (A. Pepato, pers comm) warrants further collection and study.

The aims of this paper are to highlight the value of underutilized collecting techniques for caves and provide a morphological framework for two new distinctive taxa from Nullarbor caves, southern Australia, to encourage more comprehensive studies employing integrative systematics.

Methods

The majority of Neotrombidiidae specimens were obtained through pitfall trap sampling during the Yalata Bush Blitz expedition (14 caves). These traps primarily consisted of white screw-top polyethylene containers (83 mm in diameter), buried to the rim and filled with approximately 2 cm of propylene glycol. Approximately half of the pitfall traps were baited. Baits were a cherry-sized wad of canned sardine wrapped in a square of porous kitchen cloth. These were suspended over the trap with a 25 cm cane stick (Fig. 1).

In instances where coarse flakes and stones covered the cave floor (e.g. Cave 5N-257), ramp traps were employed (P056-trap, Chemtica Internacional, Costa Rica, Fig. 2). These traps are shallow yellow plastic square trays with a covered roof and square ramps on each edge, allowing invertebrates to climb up and fall into the tray containing collecting fluid. This trap may be useful in caves when the floor cannot be excavated, or standard pitfall traps are impractical.

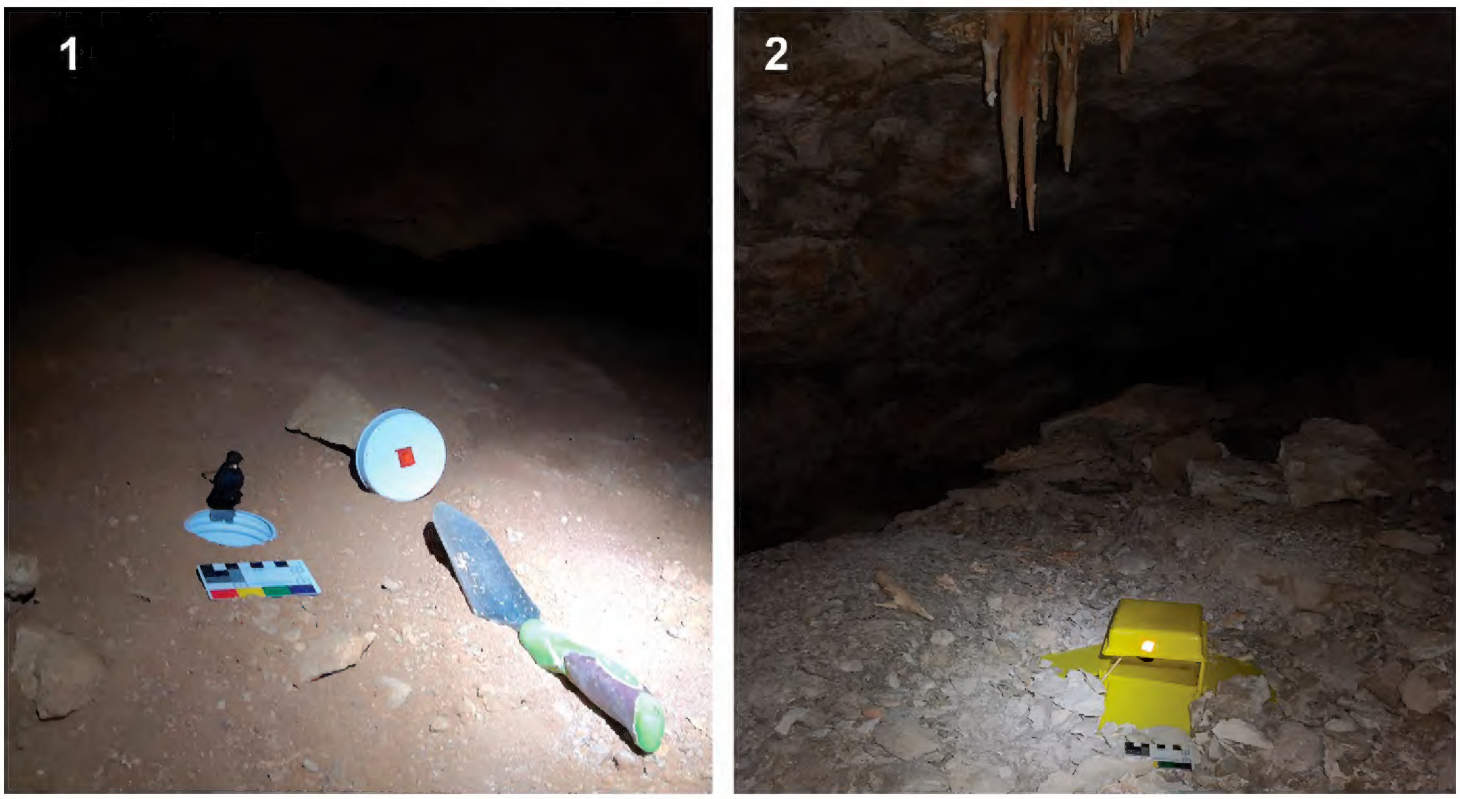
Arthropods were collected from cave sediments (18 samples) were also extracted using desiccating funnels. Such funnels are also known as Berlese or Tullgren funnels, terms now used interchangeably.

After collection, the fluid, including the original propylene glycol, was poured through a 108 μm stainless steel sieve, and contents retained on the sieve were returned to the sample container. Any extraneous material caught by the sieve was carefully inspected under a high-power (630×) dissecting microscope before disposal. During subsequent sorting steps, no fluid or sieved material was discarded without first being examined under this high magnification. Microarthropods were often concealed within sediment of similar coloration in all pitfall trap samples. It was correctly assumed that potentially interesting new microarthropods might be present but essentially invisible without microscope-assisted sorting and sieving. This meticulous procedure ensured that nearly all microarthropods are expected to have been retained in the samples, leading to the discovery of several new and sometimes unexpected records (Shaw 2022).

Mites for mounting were cleared in lactic acid, rinsed twice in distilled water, and then laddered to 25%, then at least 50% ethanol, before mounting in Hoyers medium on glass slides. The DNA of specimens remaining in ethanol was protected as far as practicable by replacing trap fluid with 95% DNA-safe ethanol and storing in -18 degree freezers.

Measurements and terminology are as initially developed for trombiculid taxonomy and defined by Southcott (1961) and Goff et al. (1982). Measurements were taken with an Axiocam 305 camera on a Zeiss AxioImager.A2 microscope. Measurements in μm were taken from images after processing in ZEN version 3.10. Stacked digital images including those used for line drawing were processed in Helicon Focus 8.2.16. Numbers given after a character are measurements in μm. Where ranges or counts are preceded by a number this refers to the holotype.

Approximate locations of caves yielding Neotrombidiidae specimens are shown in Fig. 3. Caves are fragile environments where careless visitation, looting, or vandalism can cause irreparable damage to their cultural significance, biological integrity, and archaeological or



Figures 1, 2. 1. Pitfall trap with bait; **2.** Ramp trap.

Figure 3. Approximate location of caves that provided material for this study in the eastern Nullarbor karst, South Australia. Map data 2024 (C) Google.

paleontological records. To protect these sensitive sites, specific location data is disclosed to landowners and land managers but otherwise is not shared publicly. It is securely stored in the Karst Index Database, managed by the Australian Speleological Foundation. Consistent with established protocols for Australian cave data, geolocation details are neither shared, publicly nor generalized in this study. Thus this data is treated as Category 1 under the recommendations provided by the GBIF Secretariat (Chapman 2020).

Abbreviation

SAMA South Australian Museum, Adelaide

Results

Neotrombidiidae were found to be common in various caves within the eastern Nullarbor karst. Most caves harbouring Neotrombidiidae were relatively dry. One Cave 5N-253 had clear evidence of high moisture and humidity with shallow pools of free-standing water, evidence of intermittent flooding, and a distinct mite fauna, some taxa which have only ever been recorded from highly mesic environments (Shaw 2022). Neotrombiidae were mostly obtained from pitfalls and total catches include more than 51 postlarvae, nearly all of which were adults. No males have been identified among the specimens mounted so far. Five neotrombidiid larvae were recovered from pitfall traps. One of these was a distinct and wholly new short-legged taxon found beneath the elytra of a cave beetle (*Brises* sp.; see taxonomic section). Additional specimens were obtained through desiccating funnels, including material from Cave 5N-253 (Marsh et al. 2023). To prevent unintentional over-collection of a blind troglobitic trapdoor spider (*Troglodiplura beirutpakbarai* Harvey & Rix, 2020), the caving team opted not to leave pitfall traps in this cave, so catches from this important locality were low.

Cave sediment and nest extractions were attempted for 18 caves during the main expedition. However due to the limited availability of power outlets and hence electric light bulbs at the Yalata 2021 Bush Blitz expedition base at Fowlers Bay, exacerbated by cool, wet weather, funnel extractions of cave sediment during the expedition were highly inefficient. As a result, only a few microarthropods were collected, including a single adult specimen of Neotrombidiidae. One adult Neotrombidiidae was obtained from a funnel extraction in the south passage of Cave 5N-253. However a subsequent sediment sample of just 800 ml, collected in March 2022 from beneath the entrance hole of Cave 5N-253, and extracted with unrestricted access to light bulbs, strongly confirmed the high value of standard funnel extraction methods uncovering different taxa to those found in pitfall traps, highlighting the complementarity of these techniques (Shaw 2022; see also Halliday 2001).

The body color for all collected postlarval Neotrombidiidae, when observed at a week and up to six months or more in ethanol or propylene glycol, was bright carrot-orange and lacked red pigment (Fig. 4).

Neotrombidiidae collected during the Yalata Bush Blitz are described below. This study primarily focuses on the larval stages, which currently offer greater systematic insight, and are supplemented by brief descriptions of morphotype females.

Taxonomic section

***Cruralonga* gen. nov.**
https://zoobank.org/070DA1C4-F349-47D5-BA61-5144EFC8D8B3

Type-species. *Cruralonga milnerii* sp. nov.

Included species. *C. milnerii* sp. nov., *C. gracilipes* comb. nov. (Womersley 1963a), *C. gracilare* comb. nov. (Womersley 1963b).

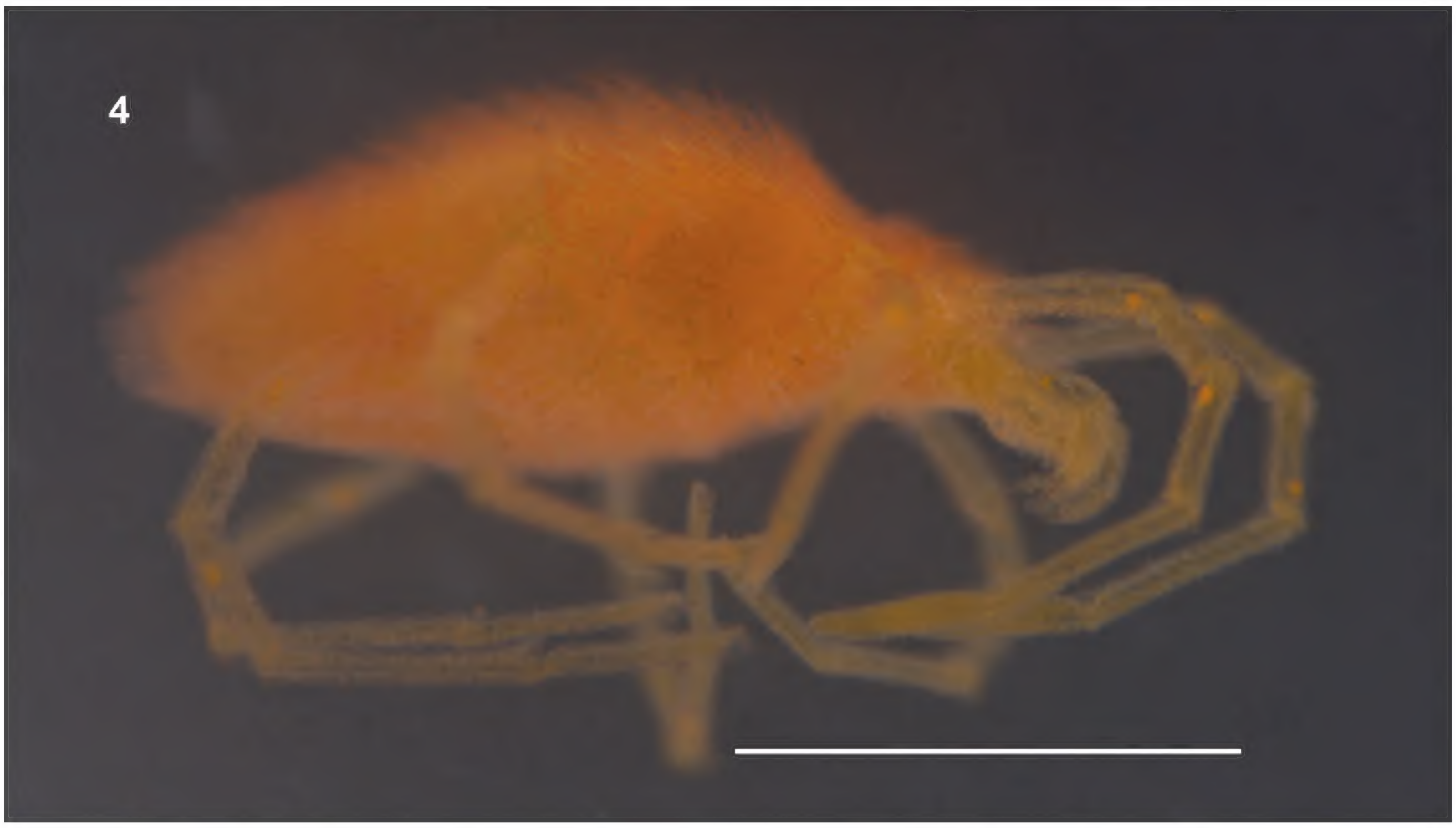


Figure 4. Funnel-extracted *Cruralonga* sp. Cave 5N-253. Scale bar: 1000 μm.

Larvae diagnosis. Scutum with straight anterolateral edges, not concave, edges not concealed by overlapping epicuticle. Anterior region of scutum moderately broad. AL setae longer than AM and PL scutal setae. Long filiform sensilla (90 or greater, up to 168 μm) and bearing only few cilia in distal quarter. Without neotrichy in *Cruralonga milnerii* and moderate hypertrichy in *C. gracilipes* (62 dorsal setae). Palps slender, palp genu elongate, more than 1.5 times genu width. Palp tibial claw bifid (and highly reduced in *C. milnerii*). Basal cheliceral segment long (ca. 90 or more), narrow. Cheliceral blade long, weakly curved. Leg segmentation 7.6.6. Urstigmata sessile against posterolateral margin of coxa I at least in Nullarbor *Cruralonga*. Coxa I separated from coxa II by a region of soft epicuticle. Ventral face of coxa I and III with conspicuous foveolate ornamentation. All legs elongate, >500 μm, slender, with tarsus length to width ratio of 8 to 12 (Table 1). Single claw on all tarsi.

Adult diagnosis. Idiosoma long and narrow with constriction in sejugal plane (between leg II and III), weak or entirely absent. Idiosoma densely clothed in triradiate (also termed trident) body setae. Median branch of body setae not expanded. Crista long to very long. Posterior projection of crista absent. Sensilla filiform, elongate, with short cilia, mostly in distal quarter, anterior area of crista elongate, spade-shaped bearing three or more pairs of tectal setae along lateral edges. Palp claw simple without accessory setae. Basal cheliceral segment elongate >240. Cheliceral blade long, weakly curved. Genital region with two elongate oval acetabula. Ventral face of all coxa with foveolate ornamentation. Legs long and slender, tarsus I length to width ratio ranges from 3.3 to 6.9 (Table 2).

Etymology. *Crura* is Latin for legs, specifically shanks, and is neuter in gender. The Latin adjective *longa* means long with feminine gender. As a whole name, *Cruralonga* is treated as neuter as per the convention with genus names ending in "-a".

Table 1. Larva measurements.

	C. milnerii sp. nov. J25686 holotype	*C. milnerii* sp. nov. J25682 paratype	*C. milnerii* sp. nov. J25688 paratype	*C. milnerii* sp. nov. J25681 paratype	*C. gracilipes* (Womersley, 1963a) holotype	*Monunguis streblida*	*N. folium* sp. nov. J25676 holotype (engorged)
IL	430	553	811	508	960	ca 300	713
IW	300	272	482	234	580	–	563
L/W	1.4	2.0	1.7	2.2	1.7	–	1.3
AA	29	35	26	27	–	11	27
AW	37	28	34	34	29	53	60
PW	95	88	92	95	89	75	80
SB	46	39	38	43	38	40	44
ASB	107	105	100	86	87	38	100
PSB	31	34	29	31	20	33	24
SD	138	139	129	117	107	71	124
AP	49	67	64	61	–	36	35
AM	40	34	–	31	41	47	50
MA	39	40	41	43	35	–	–
AL	55	48	45	47	64	54	36
PL	31	27	27	35	35	27	22
S	118/130	168	115	113	90	77	72/77
H	80	66	–	73	–	44	34
D	77/88	76	65	66/74	–	29/40	34
P	82	64	–	67	–	35	43
V	65	64	–	62	–	20/39	43
Chel base	103	103	101	101	–	–	–
cx I setae	66	68	70	77	–	–	59
cx II setae	79	75	72	78	–	–	26
cx III setae	63	67	53	64	–	–	49
CxI	45	39	57	41	–	–	34
TrI	51	47	43	45	–	–	24
bFe I	53	62	65	54	–	–	29
tFeI	87	94	85	89	–	–	34
Ge I	85	76	71	81	–	–	53
Ti I	124	129	118	116	–	–	44/44
Ta I (L)	201	215	190	202	–	–	53
Leg I (L)	646	662	629	628	526	–	261
Ta I (W)	16	20	17	19	–	–	10
Ta I l/w	12	11.2	11.2	10.6	8	–	5
Cx II	56	54	64	66	–	–	43
Tr II	42	55	34	44	–	–	28
Fe II	145	158	157	140	–	–	48/47
Ge II	78	83	83	92	–	–	36/33
Ti II	113	123	114	113	–	–	44/43
Ta II	204	213	197	210	–	–	75/73
Leg II (L)	638	686	649	665	526	–	274

	C. milnerii sp. nov. J25686 holotype	*C. milnerii* sp. nov. J25682 paratype	*C. milnerii* sp. nov. J25688 paratype	*C. milnerii* sp. nov. J25681 paratype	*C. gracilipes* (Womersley, 1963a) holotype	*Monunguis streblida*	*N. folium* sp. nov. J25676 holotype (engorged)
Cx III	68	61	68	72	–	–	37
Tr III	57	57	54	56	–	–	31
Fe III	192	188	179	183	–	–	55
Ge III	92	106	102	108	–	–	37
Ti III	159	166	146	161	128	–	44
Ta III	211	235	221	243	168	–	83
Leg III (L)	779	813	770	823	620	–	287
Ip	2063	2349	2048	2116	1672	939	822

Discussion. For larvae, dorsal setation of *Cruralonga* spp. is mildly to moderately neotrichous (24–62). *Neotrombidium* spp. have 40 seta or less, whereas *Monunguis* is highly neotrichous with an average of 136 dorsal seta. The palp genu of *Cruralonga* is more elongate (L >1.5 W) than *Monunguis* whose length is <1.5× width. Both *Cruralonga* and *Monunguis*, even when unfed, have coxa I and II spaced apart and unlike typical unfed *Neotrombidium*. *Cruralonga* and *Neotrombidium* share 7.6.6 leg segmentation, whereas *Monunguis* femur I is not divided (6.6.6). Legs of *Cruralonga* larvae are ca. twice the length found in other neotrombidiid larvae. For adults, while the body size of *Cruralonga* is similar to *Neotrombidium* spp, the chelicerae, scutal elements, palps and legs are much longer. Previously the ornamentation on coxae, here described as foveolate, has been referred to as mosaic-screened porosity (Lindquist and Vercammen-Grandjean 1971). This phrase is appealing and conveys unusual microsculpturing but the concept of a mosaic screen in this context may not be understood. Foveolate is suggested as a possible alternative, admitting that this ornamentation is less regular than standard examples of foveolate cuticle in entomology and botany.

***Cruralonga milnerii* sp. nov.**

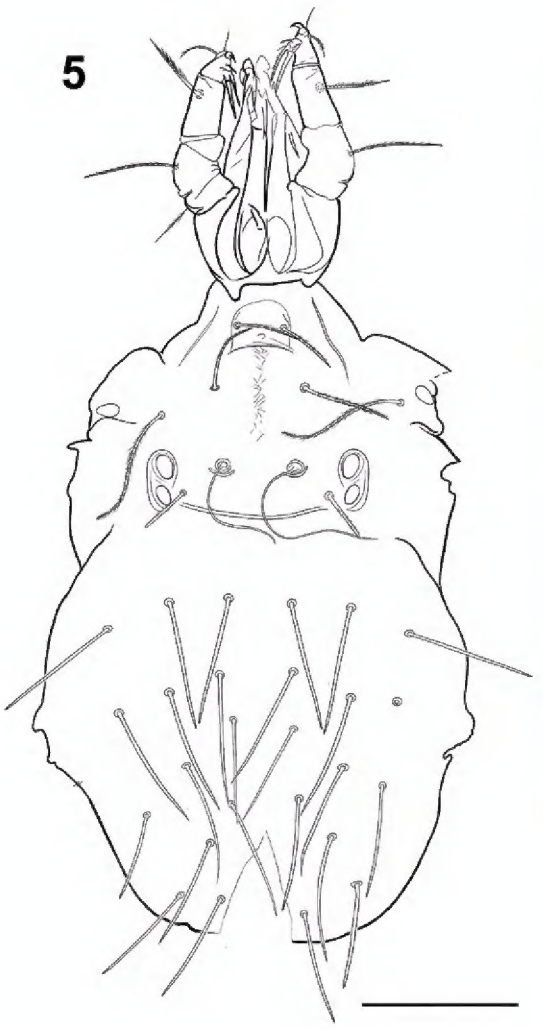
https://zoobank.org/2D7787E6-66F1-4BF5-9569-7BAEE0DB3579

Figs 4–16, 18–22

Holotype. SAMA J25686.

Type-locality. Australia, South Australia, Cave 5N-23, Yalata Indigenous Protected Area; 1 Dec. 2021 to 9 Mar. 2022, almost dark zone, ca. 20m at 110 degrees from southernmost window; unbaited pitfall trap A; S. Milner, A. Stempel, M.D. Shaw leg.

Type-specimen. ***Holotype*** • larva; SAMA J25686; mounted on microslide in Hoyer's medium; Original labels: "NEOTROMBIDIIDAE/*Cruralonga milnerii* sp. nov./ Shaw, 2025/ Holotype/larva SAMA J25686""South Australia, Cave 5N-23/ Yalata Indigenous Protected/ Area, almost dark zone/ ca. 20m at 110 degrees from/ southern-

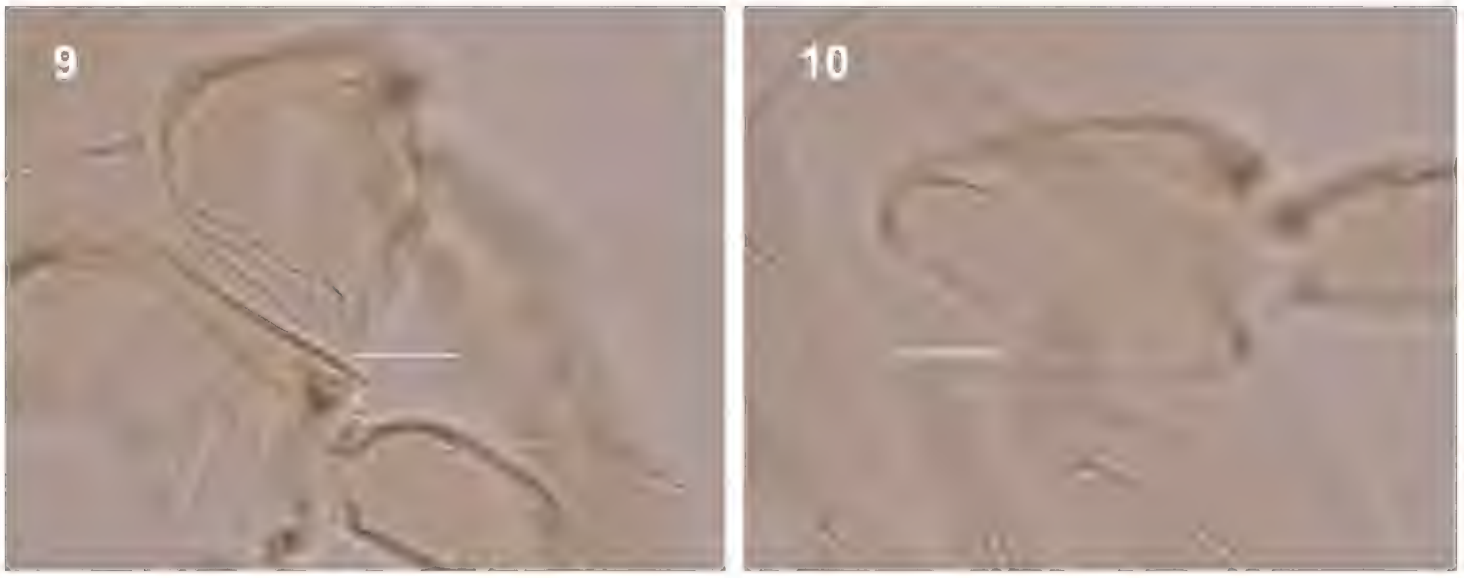


Figures 5, 6. Dorsal views of holotype larva *Cruralonga milnerii* sp. nov. SAMA J25686. Scale bars: 100 μm.

Figures 7, 8. 7. Gnathosoma, *Cruralonga milnerii* paratype larvae SAMA J25688, ventral view; **8.** Gnathosoma of same showing chelicerae. Scale bars: 50 μm.

most window/ 1 Dec 2021 to 9 Mar 2022/ S. Milner, A. Stempel, M. Shaw/ unbaited pitfall trap A/Yalata Bush Blitz 2021".

Paratypes • SAMA J25681; larva; Cave 5N-12, Yalata Indigenous Protected Area; 30 Nov. 2021 to 10 Mar. 2022; dark zone, trap B, sardine-baited pitfall trap; Steve

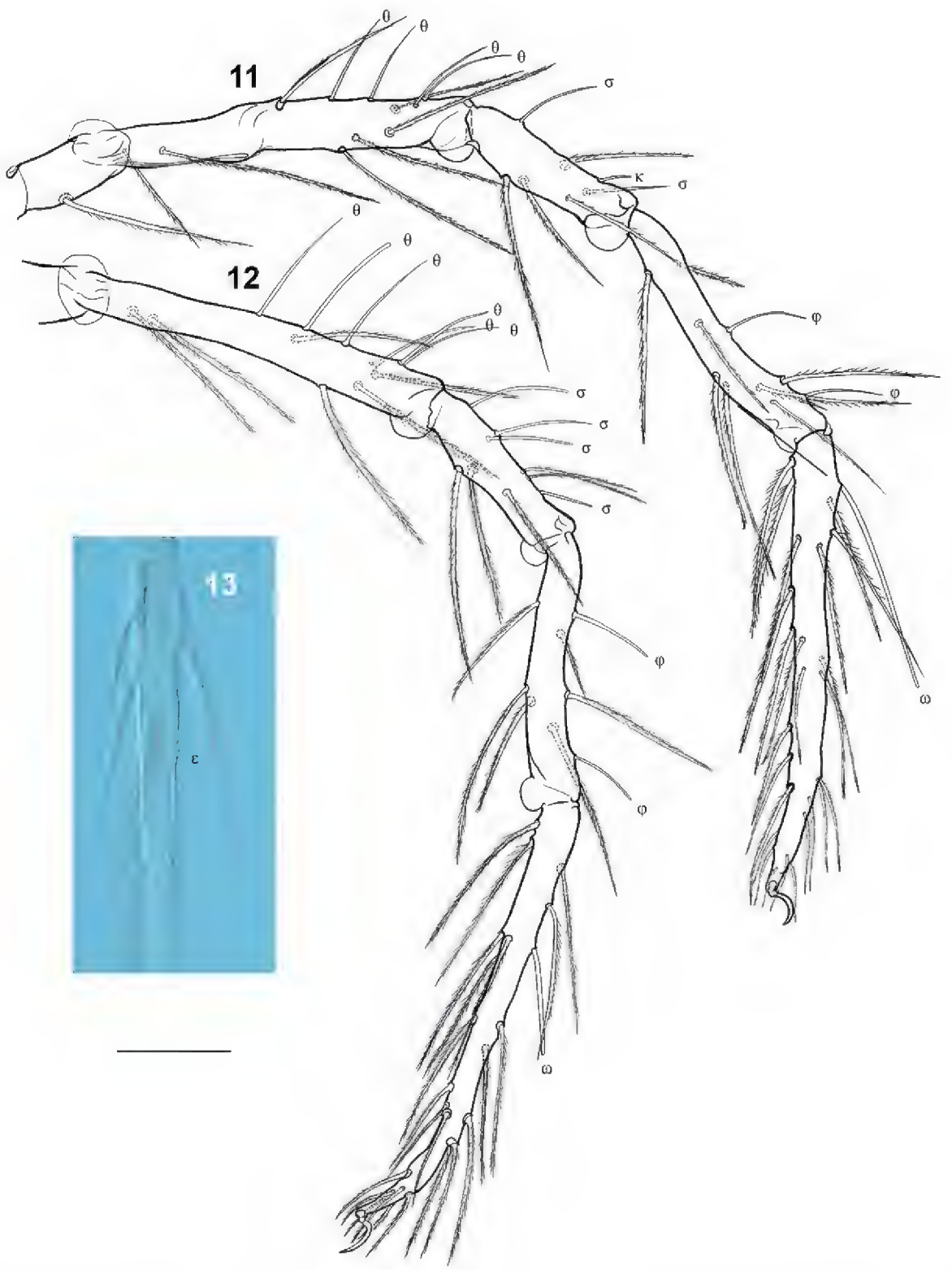


Figures 9, 10. 9. Coxa I showing foveolate ornamentation, *Cruralonga milnerii* sp. nov. SAMA J25681. **10.** Coxa III. Scale bars: 20 μm.

Milner, Andrew Stempel, Matthew Shaw leg. • SAMA J25682; larva; Cave 5N-22, Nullarbor Wilderness Protected Area, LH wall southside, ca 40m from entrance lip; 29 Nov. 2021 to 6 Mar. 2022; Steve Milner, Andrew Stempel, Matthew Shaw leg.; pitfall trap A, sardine-baited; 19.8 degrees C, 73% RH • SAMA J25688; larva; Cave 5N-111, east creekfed passage, Nullarbor Regional Reserve; 29 Nov. 2021; MSLITTER287; live extract of sediment in desiccating funnel, Matthew Shaw leg. • specimen E4; Cave 5N-23; female, same data as for holotype.

Mentioned material. • SAMA J25680; morphotype female; Cave 5N-111, Nullarbor Regional Reserve, twilight zone, SE passage where stream channel occasionally flows; 30 Nov. 2021 to 9 Mar. 2022; Steve Milner, Andrew Stempel, Matthew Shaw leg., unbaited pitfall trap C • SAMA J25683 morphotype female, Cave 5N-22, Nullarbor Wilderness Protected Area, 29 Nov. 2021 to 6 Mar. 2022, S. Milner, A. Stempel, M.D. Shaw leg., Pitfall trap A, sardine-baited, LH wall southside, ca. 40m from entrance lip, 19.8 degrees, 73% RH • SAMA J25684 morphotype female, same data as for preceding • SAMA J25685 morphotype female, same data as for preceding • SAMA J25687 Cave 5N-253, Nullarbor Regional Reserve, M.D. Shaw 2 Dec. 2021, MSLITTER263, live extraction of cave sediment from desiccating funnel.

Description of larvae. ***Dorsum:*** Length and width of idiosoma 430 (430–508) × 300 (234–300) (n = 4) in these unfed larva. Colour unknown, all larvae colourless when examined after six months in preserving fluids. Dorsal setation 2.4.6.6.6.2. The anterolateral borders of the scutum distinct, straight, lateral edges indistinct in holotype J25686 (Figs 5, 6). A slightly concave suture clearly delineates the anterior projecting portion (nasus) from remainder of scutum. This region has a well-rounded convex anterior edge. Anterior region superficially appears as a distinct shieldlet in J25682. Scutum with mild porosity in posterior half. The longitudinal axis of the scutum features a rod or band of subsurface sclerotization. The edges of this rod appear densely pocked and irregular (Fig. 5). AM setae 40, AL setae 55, PL scutal setae 31.



Figures 11–13. 11, 12. Legs I, II *Cruralonga milnerii* sp. nov. holotype J25686. **13.** Tarsus I showing position of famulus (ε, circled), SAMA J25682. Scale bars: 50 μm.

Sensilla long, filiform, mostly nude, bearing sparse array of short cilia in distal quarter. Ocular plate separate to scutum, two eyes, posterior eye smaller.

Gnathosoma: Elongate palp, palp genu approximately twice as long as wide. Minute tibial claw (8) with bifid claw-like tip. Palpal formula (fPp) is B.B.3B.6BS. Palp tarsus with subterminala, tarsala and 6 long branched setae (ca. 35). Lateral walls of gnathobase with sparse punctations only observed at 1000×, medial areas glabrous (Fig. 7). Cheliceral base long, slender, blade barely curved, almost straight (Fig. 8). Galeal setae nude, curved (17).

Venter: No sclerotized plaques or valves around anal opening. Neotrichy absent.

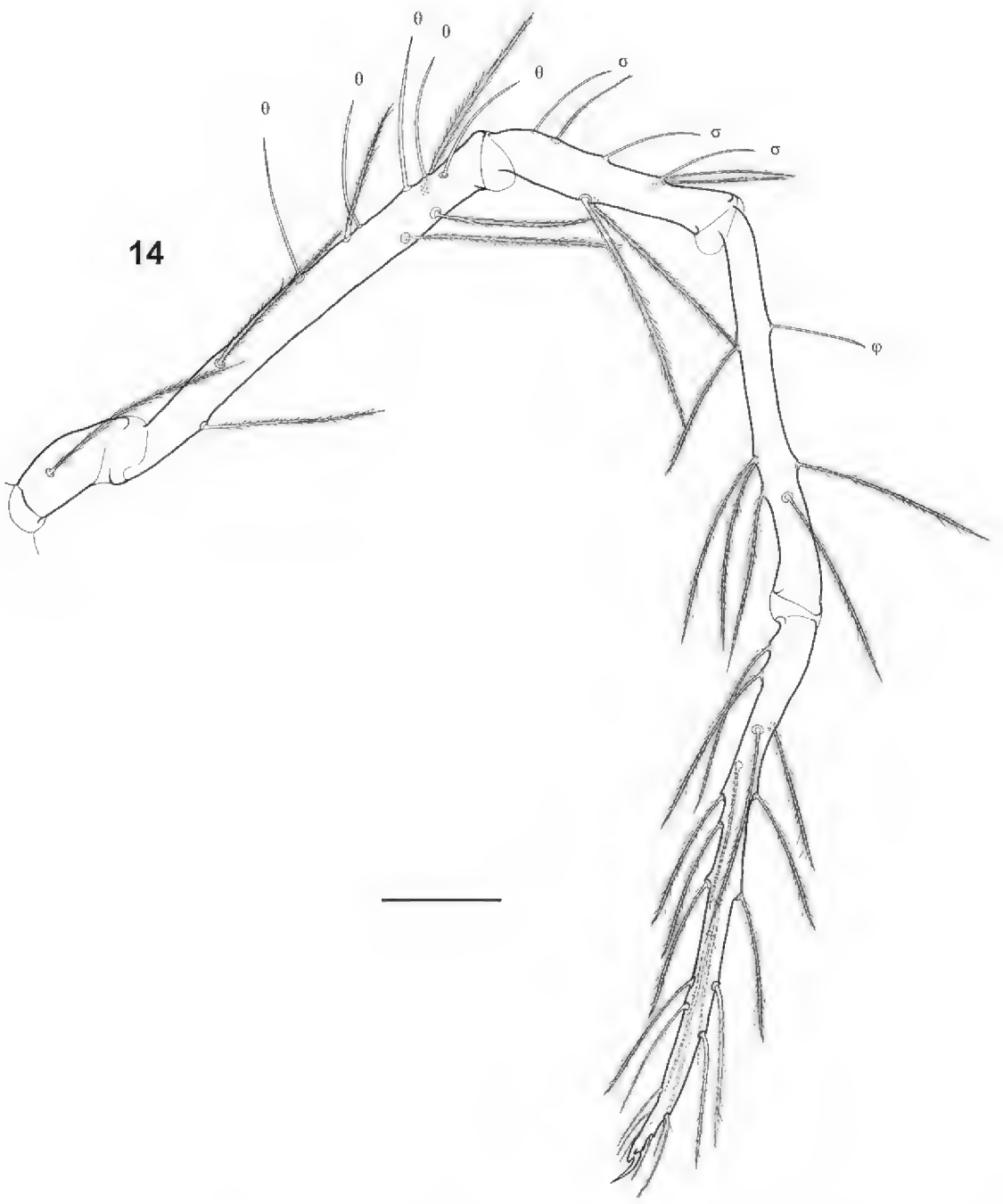


Figure 14. Leg III *Cruralonga milnerii* sp nov. holotype sp. nov. SAMA J25686. Scale bar: 50 μm.

Legs (Figs 9–14): Coxa I and II with coxal setae emerging antero-distally. Coxa III with setae emerging antero-basally. First sternal setae placed laterally at mid-level between coxa I and II. Ventral surface coxae I (Fig. 9) and posterodistad sections of coxa III (Fig. 10) with foveolate ornamentation composed of irregularly-shaped pores. Coxa II with sparse fine pores, no ornamentation.

Leg I: Tr (1n) –bFe (2n) –bFe (4θ, 5n) –Ge (1κ, 3σ, 4n) –Ti [1κ, 2φ, 8n] –Ta (1ω, 1ε, 24n).

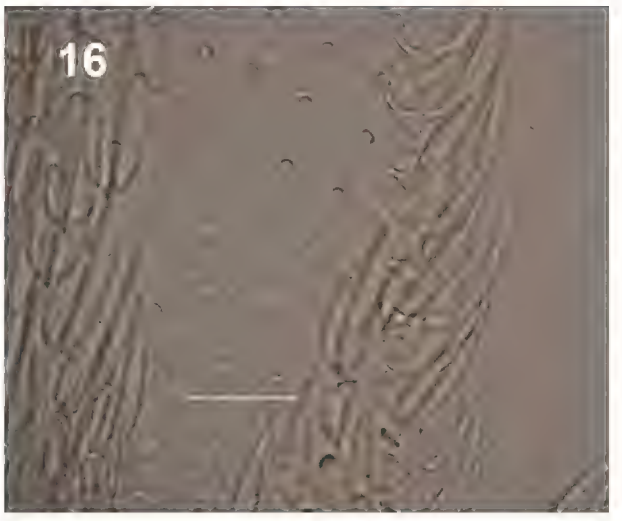
Leg II: Tr (1n) –Fe (6θ, 6n) –Ge (4σ, 5n) –Ti (2φ, 6n) –Ta (1ω, 22n).

Leg III: Tr (1n) –Fe (5θ, 6n) –Ge (3σ, 5n) –Ti (1φ, 6n) –Ta (23n).

A famulus (ε, 3 μm) on tarsus I was detected on J25682 (Fig. 13).

Legs terminate in single smooth falcate claws. Claws lack fine hairs (onychtriches) or remnants of these. Claw III is less hooked than anterior claws, curve shallower (Fig. 14).

Description of adults. Adult female *Cruralonga milnerii* as per genus diagnosis with following additional features.



Figures 15, 16. 15. Whole body of female *Cruralonga milnerii* sp. nov. paratype female E4, Cave 5N-23. **16.** Mid-lateral cuticle exposed where triradiate setae removed. Scale bars: 50 μm.

Dorsum: Idiosoma without constriction in sejugal plane in mounted specimens (Fig. 15). Dense covering of triradiate setae each borne on a low tubercle. Medial tine of setae subequal in diameter to lateral branches and slightly longer. Each seta inserts in the middle of a faintly-outlined oval-shaped platelet with fine punctations, observable where the dense covering of body setae removed (Fig. 16). Network of threads lying near the surface level of cuticle observed as an irregular mesh-like ornamentation lying between platelets. Crista elongate (Table 2), 13 wide. Anterior portion of crista a spade-shaped terminus with three pairs of setae laterally (in *C. milnerii* type series and all other examined Nullarbor *Cruralonga*, Fig. 17). Setae on crista are triradiate setae, except anteriormost pair are setulae, lacking lateral branches. Posterior eyes absent. Each anterior eye fused posteriorly with a rugose sclerotized area, considered a modified ocular plate (Fig. 18).

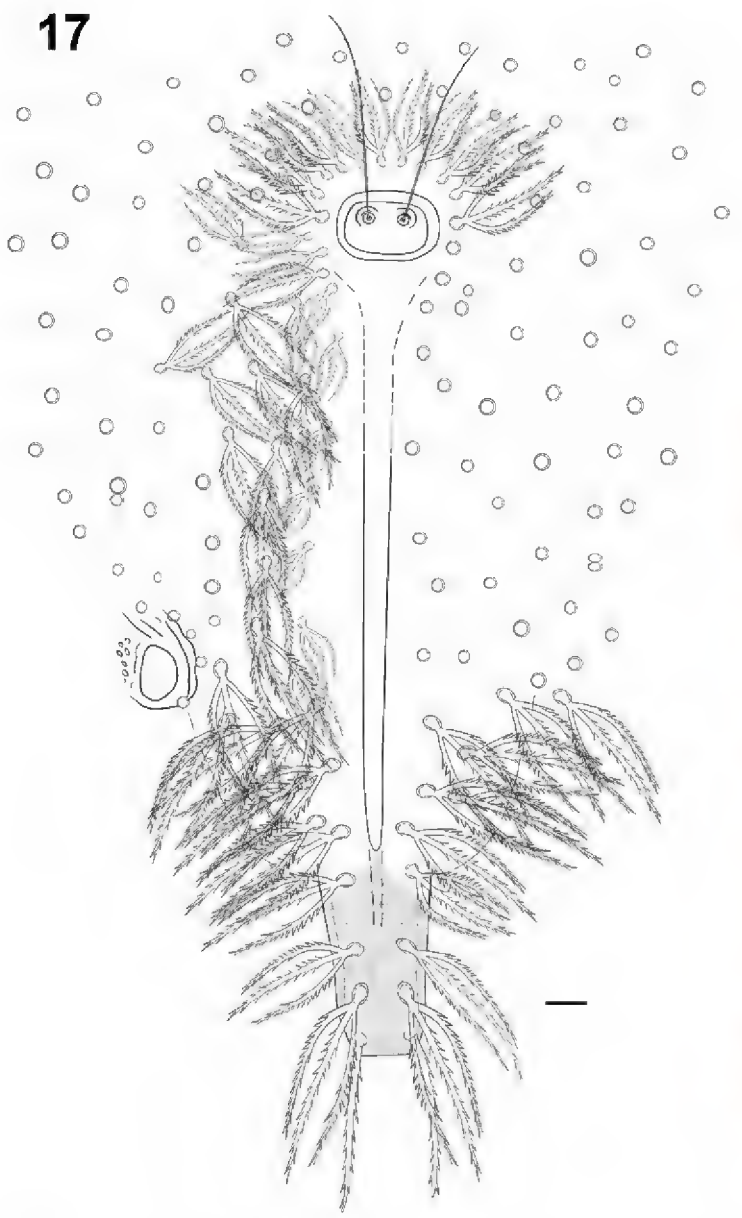
Gnathosoma: Palp claw simple, not bearing accessory setae (Fig. 19). Setulae surrounding claw slightly thickened. Palp tarsus longer than claw. Cheliceral base very long; cheliceral blade almost straight, directed forward.

Venter: Length of centrovalves similar to epivalves. Genital region of most specimens not observable due to dense obscuring body setae directed over this area. Epivalves densely covered with setulae with length and thickness matching triradiate body setae but lacking lateral branches. J25680 shows 7 setulae on each centrovalve (Fig. 20). Two pairs of long, narrow oval genital acetabula. Anal valves membranous, each bearing ca. 12 setulae (Fig. 21).

Legs: Coxa I to IV with foveolate ornamentation. Anterior internal angle of coxa I strongly modified as an angular anteriorly-directed process (Fig. 22). Paired claws smooth, claws reduced on tarsus I. Legs bear setulose setae only. Leg measures in Table 2.

Etymology. For Dr Steve Milner whose knowledge, physical efforts and material inputs were vital to access these caves. The epithet is a noun in the genitive case. (Article 11.9.1.3, International Commission of Zoological Nomenclature 1999).

Discussion. *Cruralonga milnerii* larvae exhibit distinctive elongate chelicerae and palps. These features were observed in all other Nullarbor *Cruralonga* too. Three larvae of *C. milnerii* sp. nov. were recovered from three nearby caves approximately 12 km



Figures 17, 18. 17. Anterior dorsal region of adult female *Cruralonga* sp., (eye on one side shown) SAMA J25677. **18.** Anterior eye, *Cruralonga milnerii* paratype female E4, Cave 5N-23. Scale bars: 20 μm.

apart. In two cases, larvae were co-collected with adult *Cruralonga* specimens indistinguishable from the *C. milnerii* adult from the type locality. These adults are tentatively identified as morphotype adults of *C. milnerii*. While conspecificity is suggested here as a preliminary hypothesis to support further investigation, this approach carries significant uncertainty. More data is required to test species limits and requires validation with additional larval specimens or molecular evidence.

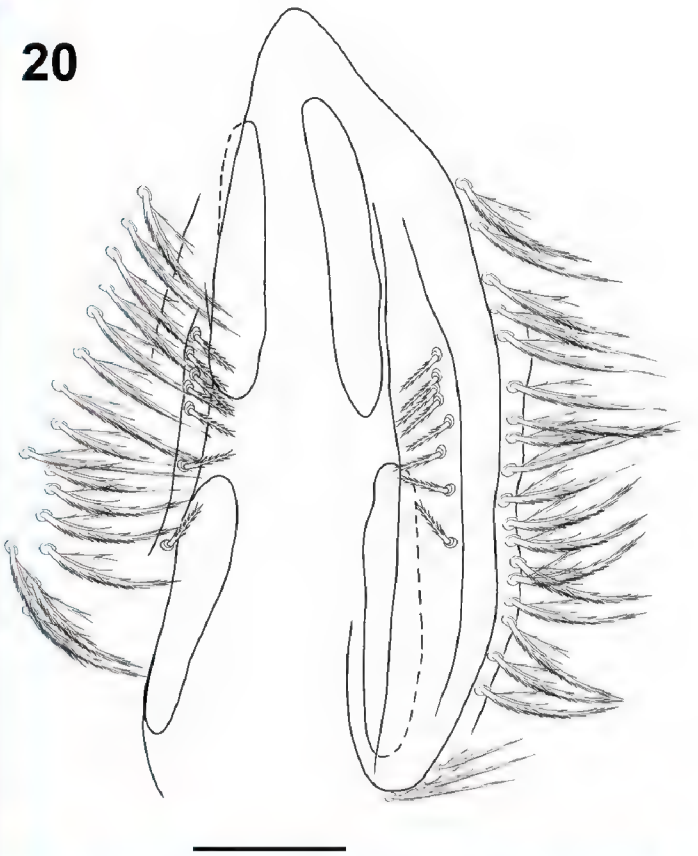
Assuming monospecificity of heteromorphic life stages based on co-occurrence can also be problematic. Southcott (1957) reported adults of the epigean *N. barringunense* and *N. neptunium* from eucalypt tree trunks at the same locality, and elsewhere noted assuming monospecificity could be "perilous" (Southcott 1954; 1961 p. 502). For related insights, see remarks for *Neotrombidium folium* sp. nov.

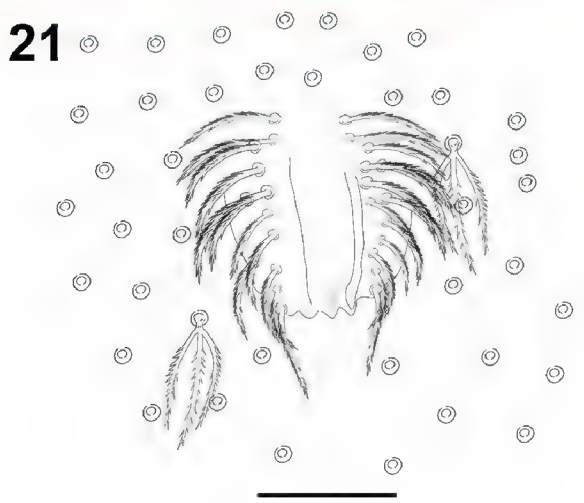
A distinctive sclerotized rod or band lying beneath the scutum, and marking its longitudinal axis, was observed in *C. milnerii* (Figs 5, 6) and is also reported for *Monunguis streblida*. However, this feature is not reported for *Neotrombidium* species. Larvae retain the posterior eye as do all other known Neotrombidiidae, however mounted adult Nullarbor *Cruralonga* lack this.

Table 2. Adult measurements.

	Cruralonga gracilare Womersley, 1963b	*Cruralonga milnerii* Cave N23, paratype	*Cruralonga* N257, J25677	*Cruralonga* N257 J25678	*Cruralonga* Cave N22 J25683	*Cruralonga* Cave N253 J25687	*N. beeri*	*N. barringunense*	*N. neptunium*
IL	1580	1437	1761	1883	1629	1437	1729	–	1350
IW	720	709	737	945	653	661	829	–	570
L/W	2.2	2.0	2.4	2.0	2.5	2.2	2.1	–	2.4
SB	–	31	26	19	–	17	–	–	–
CML	245	438	390	428	391	399	187	ca 190	165
PSAL	29	42	26	36	31	35	–	–	34
PSAW	48	54	37	47	44	47	–	–	43
Anterior setae	70	88	76	77	–	75	–	ca 60	64
S	86	135/152	–	187	–	128	–	ca 115	150
E	–	37	29	34	–	33	–	–	–
D	43	69	78	84	76	82	20–26		40
P	52	95	80	107	91	87	–	–	50
V	30	65	77	74	74	78	–	–	–
centrovalves	192	286	275	232	269	–	–	–	–
chel base seg	–	287	289	286	305	275		ca 195	–
Ch	–	49	46	63	47	56	–	–	–
TiCl	35	41	38	42	35	37	–		ca 40
PaTa	–	65	57	60	51	45	–	–	–
pa	1092	1543	1624	1514	1439	1394	135		800
pm	742	1331	1042	1243	1178	1157	507		515
pp	828	1438	1288	1411	1285	1129	580		525
Ip	3741	6147	5333	5893	5735	5343	–	ca 3100	2565
CxI	–	96	114	130	130	84	–	–	–
TrI	–	87	82	72	88	78	–	–	–
bFe I	–	270	234	296	240	239	–	–	–
tFeI	–	190	163	175	183	174	–	–	–
GeI	–	245	205	226	213	211	–	–	–
TiI	–	354	299	362	344	313	136	–	128

	Cruralonga gracilare Womersley, 1963b	*Cruralonga milnerii* Cave N23, paratype	*Cruralonga* N257, J25677	*Cruralonga* N257 J25678	*Cruralonga* Cave N22 J25683	*Cruralonga* Cave N253 J25687	*N. beeri*	*N. barringunense*	*N. neptunium*
TaI(L)	254/279	301	313	318	316	295	204	–	200
Leg I Length	1092	1543	1410	1579	1514	1394	135		800
TaI(W)	72/68	47	73	49	56	53	64	–	90
Ta I l/w	3.3–3.5	6.4	4.5/5.1	6.9	5.6	5.7	3.2	–	2.2
Cx II	–	126	100	118	111	100	–	–	–
Tr II	–	83	65	69	62	61	–	–	–
bFe II	–	213	170	225	197	167	–	–	–
tFe II	–	150	166	159	148	154	–	–	–
Ge II	–	197	134	178	172	166	–	–	–
Ti II	–	271	168	168	261	244	–	–	–
Ta II	–	291	254	285	277	265	–	–	–
Leg II Length	742	1331	1123	1202	1228	1157	507	–	515
Cx III	–	121	123	129	127	117	–	–	–
Tr III	–	98	60	99	90	76	–	–	–
bFeIII	–	213	184	192	183	185	–	–	–
tFe III	–	176	140	165	159	142	–	–	–
Ge III	–	211	184	196	188	194	–	–	–
Ti III	–	312	274	321	300	288	–	–	–
Ta III	–	307	279	297	296	283	–	–	–
Leg III length	828	1438	1244	1399	1343	1285	580	–	525
Cx IV	–	138	129	149	144	128	–	–	–
Tr IV	–	124	82	110	112	93	–	–	–
bFe IV	–	249	245	235	228	174	–	–	–
tFeIV	–	236	189	216	189	190	–	–	–
Ge IV	–	276	241	252	260	213	–	–	–
Ti IV	–	472	352	419	391	416	–	–	–
Ta IV	–	340	318	332	326	293	–	–	–
Leg IV length	1079	1835	1556	1713	1650	1507	–		725





Figures 19–22. 19. Palp tarsus and tibial claw, *Cruralonga milnerii* sp. nov. paratype female E4, Cave 5N-23. **20.** Genital area *Cruralonga milnerii* sp. nov. paratype female SAMA J25680. **21.** Anal area of same. **22.** Anterior process of coxa I (arrowed), *Cruralonga milnerii* paratype female E4. Scale bars: 20 μm (**19, 22**); 50 μm (**20, 21**).

The tagname "Neotrombidium YALBB sp10" was used in Shaw (2022) to refer to all Nullarbor cave Neotrombidiidae collected during the Yalata Bush Blitz but is now known to encompass two distinct genera as described herein.

Cruralonga gracilare (Womersley, 1963), comb. nov.

Neotrombidium gracilare Womersley, 1963b p. 150; Australia; 1 ♀; Holotype; SAMA J14200; Fig Tree Cave, Wombeyan, New South Wales; 21 Aug. 1960; B. Dew leg.

Type-specimen. Holotype adult, mounted on microslide in Hoyer's medium. Original labels: "Fig Tree Cave/Wombeyan/ 21-8-1960/ Det H. Womersley", "LEEUWENHOEKIIDAE/♀/HOLOTYPE/*Neotrombidium*/*gracilare* n. sp./ Det H. Womersley".

Discussion. *Cruralonga gracilare* is only known from postlarvae. The type locality is Fig Tree Cave, New South Wales which is also the type locality for *C. gracilipes*. As suggested in its original description, *C. gracilipes* may be a junior synonym of *C. gracilare*.

The following characters are reasons for transfer of *Neotrombidium gracilare* to *Cruralonga*: anterior sensory area is long, blunt-ended and spade-shaped hence not short, broad and rounded as in typical adult *Neotrombidium*. The arrangement of setae in this species conforms to Nullarbor *Cruralonga*. For body setae, the median tine of triradiate setae is subequal to other tines. Coxa I bears a strong, angular, anteriorly-directed process arising from its anterodistal (prolateral) face. Legs of *C. gracilare* are substantially longer than other Neotrombidiidae, approaching the condition in Nullarbor *Cruralonga* (Table 2). The holotype was examined at SAMA and conforms to the genus diagnosis. The number of eyes could not be confirmed from the holotype however based on Womersley's (1963b) illustrations and description, *Cruralonga gracilare* comb. nov. supposedly differs from *Cruralonga milnerii* sp. nov. in retaining a pair of eyes on an ocular plate.

The species identity of specimens not from the type locality and other specimens recorded from New South Wales and Victoria (Hamilton 1967) will need examination including via recollection. Womersley (1963b) states "… South Australia in bat guano" in a key for *Neotrombidium gracilare*, but "South Australia" is not mentioned elsewhere in publications, nor in Hamilton (1967). This comment is likely a *lapsus* for southern Australia, but if not, note that essentially all of the hypogean South Australian material described by Womersley is from karst areas of SE South Australia.

Cruralonga gracilipes (Womersley, 1963), comb. nov.

Neotrombidium gracilipes Womersley, 1963a p. 473, Australia; 1 ♀; Holotype; larva; Fig Tree Cave, Wombeyan, New South Wales; 21 Aug. 1960; B. Dew leg.; SAMA J14199.

Type-specimen. Holotype larva, mounted on microslide in Hoyer's medium. Original labels: "Fig Tree Cave/Wombeyan/ 21-8-1960/ Det H. Womersley", "LEEUWENHOEKIIDAE/*Neotrombidium*/*gracilipes* sp. nov./ Det H. Womersley".

Description. Sensilla with cilia along most of length. Cheliceral base 91. Coxa I and II, and their setae, obscured except for distalmost, external portions. Coxa III has a typical outline with a single long setae in internal angle. Where coxal cuticle is visible, it is seen through air spaces, and appears apparently, but probably not truly, as fine pitting. Other relevant details obscured. Womersley (1963a) figure shows 62 dorsal setae.

Discussion. This slide awaits careful remounting due to air spaces obscuring nearly all features (Fig. 23).

Figure 23. *Cruralonga gracilipes* (Womersley) holotype larva, whole body. Scale bar: 500 μm.

Singer (1971a) commented on the "unique palp chaetotaxy" of *N. gracilipes*. However, the specimen did not appear to have been observed. Womersley's (1963a) figure clearly does not depict all the setae on palp tarsus and tibia. Helpfully, cavers are sampling from this cave and others in an attempt to recollect this species.

Neotrombidium gracilipes is transferred to *Cruralonga* gen. nov. based on its description matching details for the diagnosis of *Cruralonga* larvae given here. Separate names for larval (*N. gracilipes*) and postlarval forms of *Neotrombidium* (*N. gracilare*), both with types from Fig Tree Cave, New South Wales were erected (Womersley 1963a, b). However, unless reared or sequenced specimens can be matched with types, assessment of variation at the type locality may yet be required to resolve an outstanding question of possible synonymy. This example shows that heterospecificity is not an innocuous assumption when enacted formally without sufficient evidence.

Genus *Neotrombidium* Leonardi, 1901

Neotrombidium folium sp. nov.

https://zoobank.org/ACF2B69B-4F2A-47D3-98F0-C2BF52258D70
Figs 24–32

Holotype. SAMA J25676.

Figures 24, 25. 24. *Neotrombidium folium* sp. nov. holotype SAMA J25676, phase contrast image of whole body showing engorgement. **25.** Gnathosoma, ventral view of same. Scale bars: 200 μm (**24**); 20 μm (**25**).

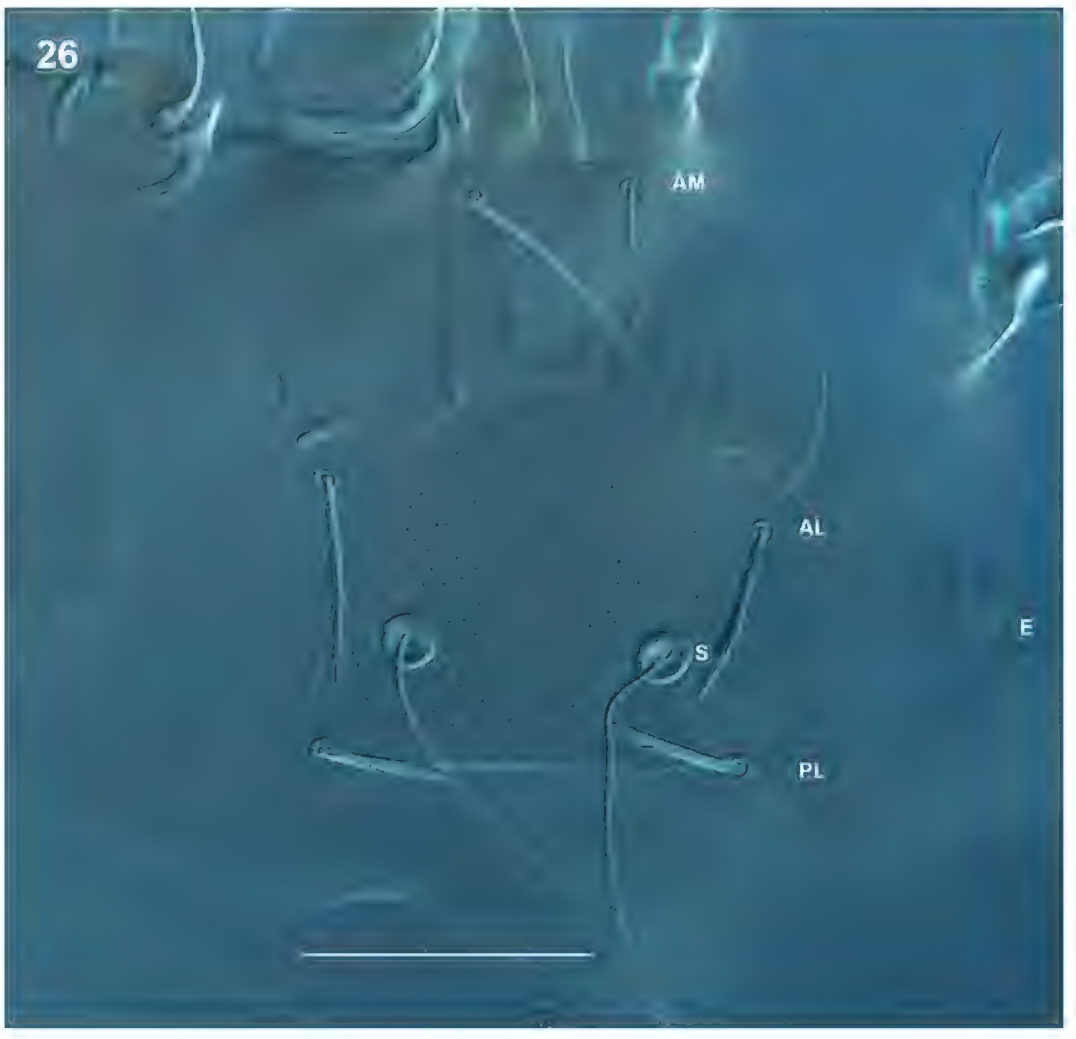


Figure 26. Scutum showing expanded anterior portion. *Neotrombidium folium* sp. nov. holotype SAMA J25676. E: paired eyes; AM, AL, PL: anterolateral, anteromedian and posterolateral setae; S: sensilla. Scale bar: 50 μm.

Type-locality. Australia, 1 larva; South Australia, Cave 5N-257, Nullarbor Regional Reserve; 27 Nov. 2021 to 7 Mar. 2022; Steve Milner, Andrew Stempel, Matthew Shaw leg.; dark zone, on loose flakes and stones fallen from roof; sardine-baited propylene glycol-filled ramp trap, trap A; Bush Blitz 2021 Yalata; in folded wing under elytra of *Brises* sp.

Figure 27. Left palp ventral view, *Neotrombidium folium* sp. nov. SAMA J 25676 holotype. Scale bar: 20 μm.

Type-specimen. Holotype larva, mounted on microslide in Hoyer's medium. Original label: "South Australia, Cave 5N-257 / Nullarbor Regional Reserve/ dark zone, on loose flakes &/ stones fallen from roof, in/ folded wing of *Brises* sp./ 27 Nov 2021 to 7 Mar 2022/ S. Milner, A. Stempel, M. Shaw/ baited ramp trap A/ Bush Blitz 2021 Yalata".

Description. ***Dorsum:*** One engorged larva, idiosoma 713 L × 563 W (Fig. 24). The anterior section of the scutum expanded laterally, hyaline, leaf-like (Fig. 26). Maximum width 93. AM setae 50 long. Sensilla moderately long 77, filiform, with short, distinct cilia along most of length. Dorsal setae in regular rows as 2.4.6.6.8.4. Standard measurements are given in Table 1.

Gnathosoma: Short, broad, palp segments (Fig. 27). Palp genu compact, length (16.9) similar to width (16.7). Hypostomal setae branched, 48 long. Gnathobase wall with fine punctuations on lateral edges. Palpal formula (fPp) is B.N.3N.5B2NS. Palp tibia with 3 setae, all nude, the dorsal seta (near tibial claw), a stout rod 8 long. Palp tarsus bearing 7 branched and 2 nude setae plus subterminala and tarsala. Palpal tibia spur bifid, with subequal broad and somewhat flattened tines, not claw-like, ventral tine broader and rounded.

Legs: Leg segmentation 7.6.6, with femur I divided. Coxa I triangular in outline, internal width reduced and heel-like, external width produced (Fig. 28). Coxa I and III ornamented, irregularly foveolate (Figs 28, 29). Coxa II with pitting only (Fig. 28). Coxa I and II setae positioned apically. Coxa II seta a curved pointed spur (27 μm, Fig. 28). Coxa III with seta positioned anterobasally. Coxa I and II separated by their own width in this engorged specimen. Many leg segments with internal ring-like thickening. All tarsal claws borne on stalk-like apices. All claws shaped as shallow curves, not strongly hooked or falcate.

Leg I: Tr (1n) – bFe (2n) –tFe [2θ (proximodorsal 17, distodorsal 20), 5n (3d, 2v)] –Ge [4σ, (distodorsal 14, two proximodorsal 14, distoventral 21), 1κ (thorn-like microgenuala 5), 5n] –Ti [2φ (proximodorsal 20, distodorsal 19), 7n (including distodorsal mastiseta 39)] –Ta [1ω (mid-dorsal 15), ca18n (including fine, mostly smooth mastiseta 33)].

Leg II: Tr (1n) –Fe (2θ, 6n) –Ge (1σ, 1κ, 4n) –Ti [2φ, 7n (including fine, mostly smooth mastiseta 45)] –Ta [1 ω, 1ε (stout famulus, 4), 20n].

Leg III: Tr (1n) –Fe (2θ, 6n) –Ge (1σ, 4n) –Ti (1φ, 6n) –Ta (16n).

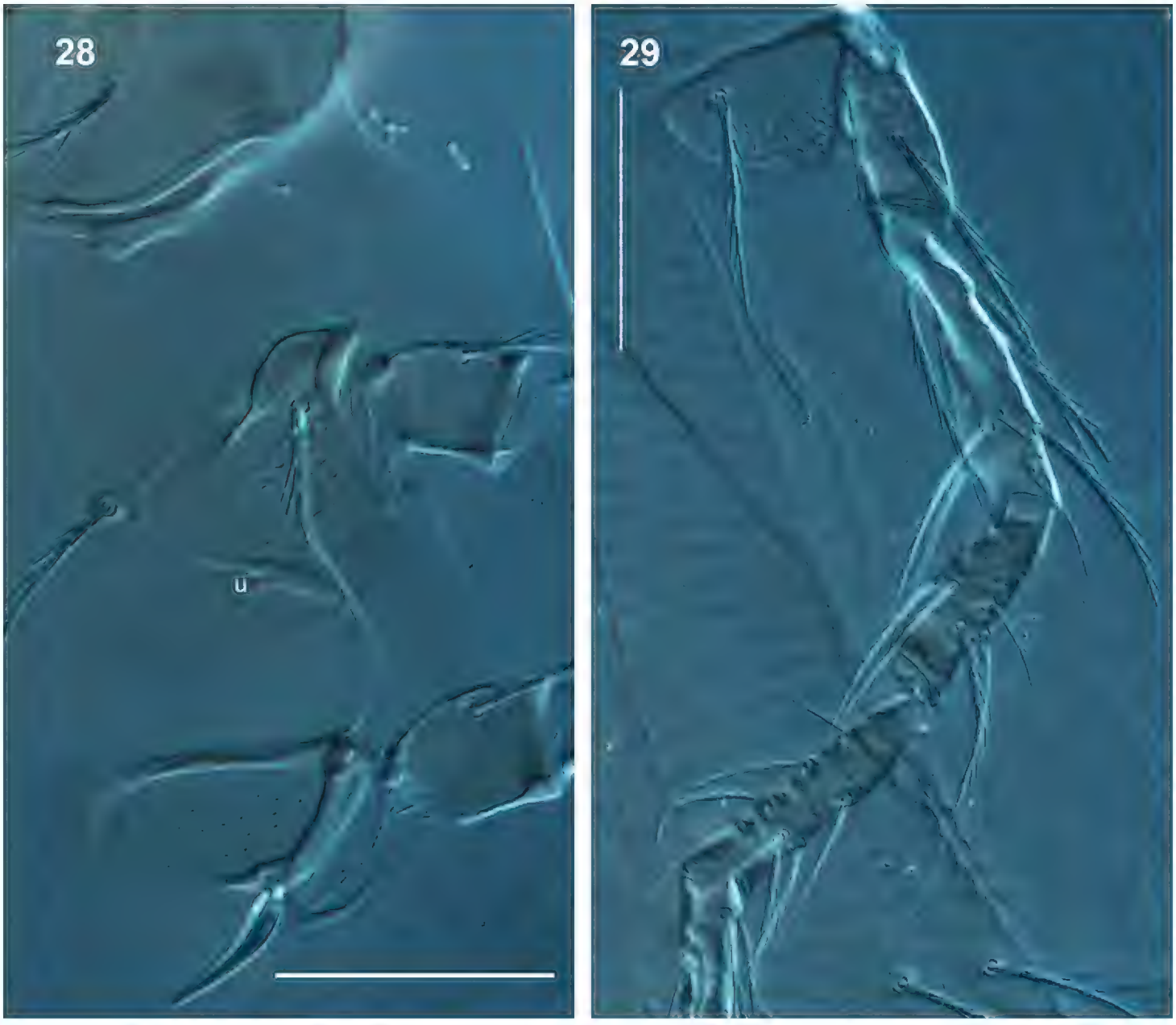
Etymology. Folium is Latin singular nominative for leaf and refers to the anterior section of the scutum. Gender: neuter, standing in apposition to the generic name (article 11.9.1.2., International Commission of Zoological Nomenclature, 1999).

Discussion. This record is the first neotrombidiid from a troglophilic beetle, and the only known host for an Australian neotrombidiid. This specimen was found easily during a rapid search under the elytra of ca. 20 specimens of the many *Brises* sp. (Tenebrionidae) collected during cave pitfall trapping. It was loose in a fold of the wings – so its precise attachment site is unknown, and might be the wing itself, rather than dorsal cuticle. Two *Neotrombidium* species have been recorded from, and even attached to wings (Lindquist and Vercammen-Grandjean 1971).

Apart from *Monunguis* parasitizing streblid flies, most host records for Neotrombidiidae are beetles inhabiting subcortical habitats, including species from families such as Cerambycidae, Cleridae, Elateridae, and Tenebrionidae. Two *Neotrombidium* species were attached to the tarsi of carabid beetles in Iran (Noei et al. 2017).

Additional tenebrionid host records are the subcortical *Alobates* sp. (Tenebrionidae), parasitized by *Neotrombidium tenebrione* Lindquist and Vercammen-Grandjean, 1971, from Washington, D.C., and by the highly similar *Neotrombidium beeri* Singer, 1971a, from Kansas. Notably, Singer (1971b) successfully reared *N. beeri* nymphs to adulthood by feeding with eggs of *Tenebrio molitor*.

Coxae I and II being well separated (Fig. 28) might initially argue against the placement of *N. folium* sp. nov. within *Neotrombidium*, given the emphasis on this

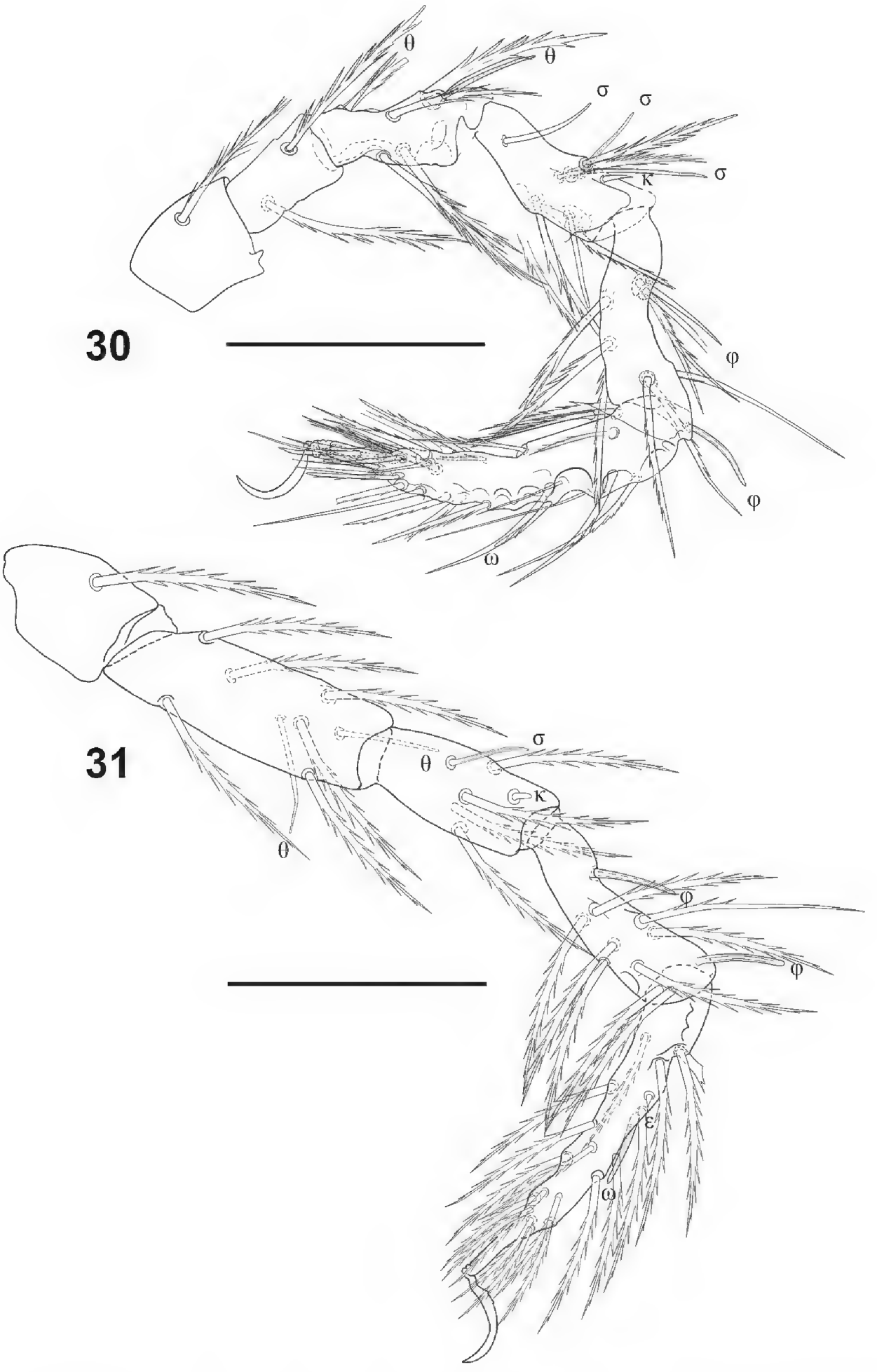


Figures 28, 29. 28. Coxa I and II showing coxa I ornamentation, and coxa II spur-like seta, *Neotrombidium folium* sp. nov. holotype larva SAMA J25676; u: urstigmata. **29.** Leg III coxa to tibia. Scale bars: 50 μm.

character in early literature. However, in *N. khanjanii* Noei, Hasanvand, and Saboori (2017), engorged specimens also exhibit well-separated coxae. For *N. khanjanii* and *N. folium*, separation might result from the synthesis of new cuticle during engorgement (cf. neosomy, Audy et al. 1972).

The expanded anterior region of the scutum of *Neotrombidium folium* appears unique. The form of the scutum highlights and extends the scutal variability known for the Trombidioidea. For Neotrombidiidae, scutal features to consider are to be AM setal insertions on an anterior projection, and in many cases the projection having a discernible posterior border, as a groove or suture, that marks the boundary between the projecting region and the remainder of the scutum, in various *Neotrombidium spp* and in *Cruralonga milnerii* sp. nov. (Fig. 5). The anterior projection in Leeuwenhoekiinae have AM setae inserted on the main part of scutum, not on the projection (nasus). I am not aware of Leeuwenhoekiinae where there is a line or groove delineating these two regions. These differences in form and position may not have been considered using homology criteria.

The distinctive characters of *N. folium* sp nov., viewed without a phylogenetic perspective, might be assumed to represent a generic novelty. Apparent taxonomic dis-



Figures 30, 31. 30. Leg I *Neotrombidium folium* sp. nov. holotype SAMA J25676. **31.** Leg II (ibid.). Scale bars: 50 μm.

tance does not necessarily translate to robust systematic placement however. A straightforward count of branched setae on the legs closely matches those of *Neotrombidium* species, for instance the number of branched/normal seta on femora matches 7.6.6

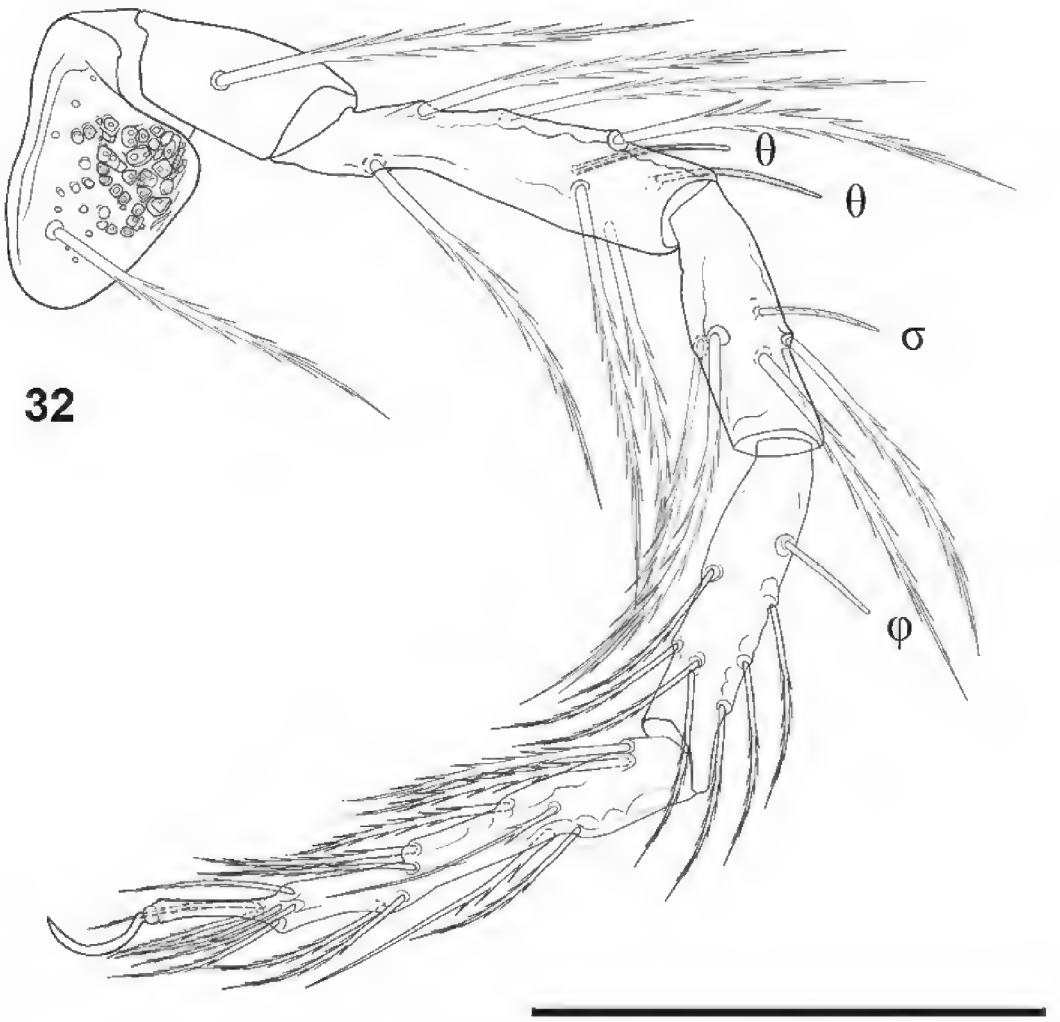


Figure 32. Leg III *Neotrombidium folium* sp. nov. holotype SAMA J25676. Scale bar: 50 um.

(Lindquist and Vercammen-Grandjean 1971). The numerous sensory setae (e.g. leg I–III have genualae as 4.2.1) while an increase compared to *Neotrombidium*, could even be autapomorphic features evolved as troglomorphic adaptations. If a new genus is proposed now, there is only a single, difficult, specimen which would become the type species. It would be more rewarding for researchers to use the leads provided here and study more material before embarking on further systematic revision.

The type locality of *N. folium* sp. nov. is a relatively simple cave of tiny volume and ca. 25 m across in its maximum dimension. Superficially, it seemed lifeless, dry and stony. We considered not placing traps at all. Yet remarkably two genera of Neotrombidiidae co-occur here. In addition to *N. folium*, the same ramp trap yielded two *Cruralonga* females (SAMA J25677, J25678). Candidates for postlarvae of *N. folium* remain uncollected.

Discussion

Collection

Neotrombidiidae have only been reported from two other Nullarbor caves (6N-70 Firestick cave and 6N-160 Dingo Donga Cave; Eberhard and Moulds 2007) as far as I am aware. These mites were identified as *Neotrombidium* sp. Many postlarval Ne-

otrombidiidae were pitfall-trapped during the Yalata Bush Blitz, and from most caves in which pitfall traps were set. Given the paucity of cave-inhabiting Neotrombidiidae reported from collections worldwide, this seems interesting. Adoption of pitfall trapping was a consequence of reading Lundqvist's et al. (1999) survey of six Scandinavian caves and their experience is recounted here: "The numbers of individuals [n = 1765] and species [37 species of Gamasina] in this investigation exceeded by far those usually reported from investigations of caves in Europe, probably due to our use of pitfall traps". For Nullarbor collections it was clear that the use of baits increased catches of a wide range of scavenging arthropods in Nullarbor caves. Indeed, in the older literature, the early implementations of pitfall traps are referred to as "Barber traps". The original Barber traps were baited pitfall traps in caves used for collecting invertebrates such as trechine carabid beetles, which were enticed by raw meat and soft cheese bait. Traps were placed under protective stone slabs (Barber 1931). The Yalata Bush Blitz catches are a confirmation of the usefulness of both baited and unbaited pitfall traps for collecting of the scavenging and predatory arthropod groups that occur in Nullarbor caves. However, pitfall traps are selective, and desiccating funnel extraction remains a vital technique to assess the truly broad diversity recoverable from cave sediment. It is clear that Australian cave faunal lists could double their known diversity when such techniques are employed (e.g. Halliday 2001).

Troglomorphism

Relative to other Neotrombidiidae and many other Trombidioidea, *Cruralonga* has increased numbers of sensory setae, elongate sensilla, elongate legs and other appendages, loss of the posterior eye in adults, and possible reduction in pigment. These characteristics could represent troglomorphic modifications or adaptations for a cave environment. The larvae of the cave-dwelling species *C. gracilipes* and *milnerii* are characterized by relatively long sensilla. Although all Neotrombidiidae possess filamentous sensilla, those of *Cruralonga* are the longest recorded within this family.

Sensory genualae on the anterior, mid, and posterior legs of *Cruralonga milnerii* sp.nov. larvae number 3.4.3 whereas it is 3.2.2 in the cave-inhabiting *Monunguis*, compared to 2.1.1 or 3.1.1 in reviewed *Neotrombidium* spp. (Lindquist and Vercammen-Grandjean 1971). Most striking is the large number of femoralae: 4.6.5 in *Cruralonga milnerii* sp.nov. compared with 3.2.2. in *Monunguis*, and 2.2.2 in *Neotrombidium* spp. This count of supernumerary sensory setae on proximal leg segments, with 2–2.5 times more sensory setae than epigean *Neotrombidium*, seems unusual for parasitengone larvae.

For *Neotrombidium folium* sp nov. the apparent increase in sensory setae in this cave species, though not as marked as Nullarbor *Cruralonga*, remains noteworthy compared to confamilials, as it is a short-legged taxon (Ip = 822). Hence the number of sensory setae is not readily attributable to a simple developmental mechanism such as a change in leg length as has been suggested for cavity nest specialists (trombiculid nymphs; Nadchatram 1979).

Cruralonga has much longer legs than epigean *Neotrombidium*. The sum of leg lengths (Index pedibus, Ip), usually intended as a size indication for larvae, is here repurposed as a pointer for possible troglomorphism (Table 2). Larvae for seven *Neotrombidium* species on various continents have Ip ranging from 755 to 944 μm and *Monunguis streblida* proportions are also within this range as 939. In contrast, for *Cruralonga gracilipes* (Womersley) this measure is 1672 and for *Cruralonga milnerii* it is up to 2349 (Table 1). *Cruralonga* have relatively elongate, slender appendages as shown by comparisons of leg IV length with idiosoma length, and the ratio of tarsal length to width.

These leg proportions are reflected in adult females too. The average body length of Nullarbor *Cruralonga* females is only 22% longer than the smallest *Neotrombidium* adult (*N. beeri* Singer, 1971a), yet legs are proportionally much longer. Sum of leg lengths (Ip) for the epigean bark-dwelling NE Australian *N. neptunium* sum only to 2565 μm. Similarly for *N. barringunense* Hirst, 1928 total leg lengths are here estimated at ca. 3100. In contrast, the cave-dwelling *Cruralonga gracilare* sum to 3741, and Nullarbor *Cruralonga* females range from 5333 to 6147. As with some other long-legged Trombidioidea (Mąkol 2007), leg IV of *Cruralonga* approximates idiosomal length. In comparison, leg IV of the epigean *Neotrombidium beeri* is 50% of idiosomal length (Singer 1971a).

Future work

Looking for interesting contrasts in morphological evolution, biologists are drawn to caves and other hypogean habitats. The sometimes striking contrasts between above and below ground taxa are more likely to be informative if contrasts are replicated and there is enough variation in relevant troglomorphic traits. How useful might the contrasts glimpsed here prove? Regardless of whether they prove informative in a comparative sense, they do seem unexpectedly tractable. Favorable to research prospects are pitfall trapping and desiccating funnels providing good numbers of both adult and larval Neotrombidiidae. Note that locating *Cruralonga* larvae is expected to become easier once their host/s are identified. This prospect could be combined with direct counts and measures of their exposed sensory organs. If observations here are replicated across the Nullarbor karst, the largest area of arid limestone karst in the world, this system could prove informative for understanding cave adaptation. Any future advances in understanding will depend on, and benefit greatly from, the active involvement of First Nations custodians and cavers.

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